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GROSS ALPHA AND BETA ACTIVITY CONCENTRATIONS IN GROUND WATER SAMPLES FROM BREWERIES IN NIGERIA AND ITS POTENTIAL RADIOLOGICAL HAZARDS.

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ABSTRACT

Background: Ingestion and absorption of gross alpha and beta (Gα and β) emitting radionuclides into human body can pose a number of health hazards such as cancer and deoxyribonucleic acid (DNA) damage. Measurement of Gα and Gβ RAC in ground water used in beer brewing in Nigeria with help to estimate the population at risk. So far, the Gross alpha and Gross Beta Radionuclides activity concentration (Gα and Gβ RAC) for quality assurance of ground water samples from different brewery locations in Nigeria have not been determined. The aim of this study was to assess gross alpha and beta radionuclide activity concentration in ground water samples from breweries in Nigeria and their potential radiological hazards.

Materials and Methods: A cross-sectional survey design was adopted. A total of fourteen (14) samples of ground water were collected from respective studied breweries in Nigeria. About fifteen (15) ml/L sample of 1 mole per cubic decimeter (1 mol/dm^3) of concentrated Trioxonitrate (v) acid (HNO_3) was added to the ground water sample at the collection point to prevent the adsorption of the radionuclides to the inner wall of the container. Further sample preparation and analysis were carried out at Radiation Protection Institute (RPI), Ghana Atomic Energy Commission (GAEC), Accra, Ghana using Method 900.0 of the US Environmental Protection Agency. Data were collected using Canberra iMatic™ Automatic low background gas-filled counter to determine the gross alpha and gross beta radionuclides activity concentration in the ground water samples analyzed.

Results: The mean value of Gross alpha activity concentration in ground water samples from breweries in Nigeria was 0.370±0.34 Bq/L and that of gross beta activity concentration in ground water samples was 0.193±0.26 Bq/L. Site by site brewery analysis of ground water samples revealed that Imo state brewery (Awo-Omama) recorded the highest value of gross alpha activity concentration with a means value of 0.953 Bq/L while the least value was recorded in River state (0.083 Bq/L). Anambra brewery recorded the highest gross beta activity concentration in ground water with a mean value of 0.695 Bq/L while the least value was recorded in River state (0.006 Bq/L). The gross alpha (0.467±0.29 Bq/L) and gross beta (0.494±0.10 Bq/L) activity concentrations were found to be higher in ground water samples from the northern region when compared with the gross alpha (0.219±0.26 Bq/L) and gross beta (0.223±0.0.31 Bq/L) activity concentrations in ground water samples from south-south and south-east regions of Nigeria respectively. Ground water samples from almost all the breweries in different geographical locations in Nigeria recorded significantly higher values of activity concentrations.

Conclusion: Gross alpha radionuclide activity concentrations in ground water samples from breweries in Nigeria, based on World Health Organization (WHO) recommended safe guideline were generally not safe whereas the gross beta activity concentrations were relatively safe.

Introduction

Radionuclides can enter the human body through four main pathways; namely ingestion of contaminated food, water etc.; inhalation of radioactive gas such as radon gas and radioactively contaminated dust particles into our lungs; injection of radiopharmaceuticals during diagnosis or as part of medical therapy in nuclear medicine and absorption of radionuclides through the breaks or skin surfaces into the body [1]. The concentration of radionuclides in our environments such as in food and water we ingest primarily varies geographically due to geological variations of different environment [2] with the geochemistry and geophysics of such environment also playing a role in radionuclides migration from the soil and rock to food and water [3]. Human and animal studies have shown that no detrimental radiological health hazard such as incidence of cancers are expected from ingestion of radioactivity contaminated water if the radionuclides activity concentration is below the recommended reference dose levels [4]. The recommended safe guideline of activity concentrations in water are 0.1 Bq/L for gross alpha activity and 1.0 Bq/L for gross beta activity [5].

Beer is known to contain about 90-95% of water and about 5-10% of grains (barley, wheat, maize, rice, sorghum, hops and millet), yeast etc [6]. Ground water from different brewery locations in Nigeria may be contaminated with radioactive materials due to variation in geological formation. Gross alpha emitters (Uranium-238, Radium-228 and Polonium-210) and beta emitters (Potassium-40 and Lead-210) in water, when ingested can pose a number of health hazards such as cancer and deoxyribonucleic acid (DNA) damage. The most important radionuclides associated with the contaminations of our environment and internal irradiation include Americium-241, Chromium-241, Plutonium-238, Plutonium-238, Plutonium-239, Radium- 222, Radium-226, which are alpha emitters; Calcium-41, Carbon-14, Cesium-134, Strotium-89, Strontium-90, and Tritium which are beta emitters [7]. When alpha particle emitting radionuclides are ingested via water source, their hazardous effects are twenty (20) times more as a result of their high linear energy transfer and relative biological effectiveness [8]

The hazardous effects of radionuclides in water when they deposit in the tissue of consumers depend on the nature of the radioactive contaminant, the quantity of contamination and tissue affinity [9]. Consequently, there is great concern about the possible radiological health hazards to consumers of ground water and beer products brewed with ground water sample from different geographic brewery locations in Nigeria, most especially in southern parts where beer consumption is considered as part of socio-cultural norm [10]. So far, there is paucity of data on the gross alpha and gross beta activity concentrations in water samples used in different geographical brewery locations in Nigeria which will help to guarantee a safe low alpha and beta activity concentration levels, thus the rationale for this study.

Materials and Methods

Study Design

A cross sectional survey design was adopted. This was designed for the researcher to assess the presence or absence of an outcome and presence or absence of an exposure at a specific point of time without the need for follow-up.

Location of Study

All registered and operating brewery factories in Nigeria which will included:

1. Nigerian Breweries Plc factories located in
   - i. Lagos State- Abebe village road, Iganmu, Lagos state, Industry Road
   - ii. Abia State- Ogbor hill industrial Layout, Obiangwu, Aba.
   - iii. Kaduna State-No1 Makera Road, industrial layout and No 1 Kudenda industrial area, Nnamdi Azikiwe Expressway Kaduna bypass.
   - iv. Enugu State- Amaeke in 9th Mile.
   - v. Ogun State- Epe Road, Imagbon village Ijebu-ode and Km 38 Lagos Abeokuta Expressway Sango Ota both in Ogun state.
   - vi. Imo state- KM 24 Owerri/Onitsha road, Awo-Omama.
2. Guinness Breweries located in:
   - i. Lagos State- Km 24 Oba Akran Avenue.
   - ii. Edo State- 49 Oregbeni industrial Estate, Ikpoba Hill, Benin city.
3. International Breweries located in:
   - a. Osun state- Lawrence Omole Way, Omi-Asoro, Ilesa.
   - b. Anambra State- SABMiller Drive, Harbour Industrial Layout, Onitsha.
   - c. River State- 186/187 Trans-Amadi Industrial Layout, Oginigba, Port Harcourt
4. Champion breweries PLC located in: Akwa-Ibom State- Industrial Layout Aka Offot, Uyo.

Ethical Clearance

In line with Helsinki declaration 1964, ethical approval was obtained from the research ethics committee of the Faculty of Health Sciences and Technology, Nnamdi Azikiwe University, Nnewi Campus and Ministry of Health, Anambra state.

Sample Size

Sample size comprised of:

i. Eight (8) ground water samples from twelve (8) brewery locations of Nigerian Brewery Ltd.
ii. Three (3) ground water samples from International Breweries from three (3) brewery locations in Nigeria.
iii. Two (2) ground water samples from two Guinness brewery locations in Nigeria.
iv. One (1) ground water samples from Champions Brewery Plc location.

Sample collection

Method 900.0 of the US Environmental Protection Agency was used during the collection and preparation of the samples as follow:

Samples of ground water was be collected directly into two liter (2 L) of plastic kegs (polyethylene containers) after washing the containers properly and rinsed with the water sample to be collected. About 15ml/L of validated 1 mole per cubic decimeter (1 mol/dm^3) sample of concentrated Trioxonitrate (V) acid ($HN0_3$) was added into the collected ground water samples at the point of collection using a syringe, gloves and a face-mask. The addition of concentrated Trioxonitrate (V) acid ($HN0_3$) served to preserve the radionuclides present in the water samples by preventing the adsorption of radionuclides from water to the inner walls of the containers (Semkow, 2001 and WHO, 2014). The taps was first turned on at its full capacity for about three (3) minutes to purge the plumbing system of any water which might have been there for some time. The taps flow rate was subsequently reduced to attain steady turbulence and radon loss before collecting the water into the kegs [11,12].

Crocked bottled beer samples at the point of collection do not require any preparation. The ground water samples were sent to the Radiation Protection Institute (RPI), Ghana Atomic Energy Commission (GAEC), Kwabenya Accra, Ghana, where they were further prepared and analyzed for gross alpha (α) and gross beta (β) activity concentration.

Samples Preparation

APPARATUS: Laboratory beakers, petri-dishes, hot plate, infra-radiator lamp, Experimental (Digital) weighing balance, planchet, cotton wool.

REAGENTS: Acetone and vinyl acetate.

PROCEDURE: The beakers, crucibles (petri-dishes), planchet and spatula were washed properly, rinsed with clean water and sterilized using acetone. Then the apparatus were kept and dried inside the oven. A little quantity of the ground water sample was used to rinse the beaker twice so as to ensure that there was no cross contamination before evaporation. About one liter (1L) of the ground water samples was filtered on a filtration system set up and transferred into a one liter (1L) beaker. Two millimeter (2 ml) of HNO_3 was added to all the samples to maintain and to liberate metals and dissolve organic particles. It was left to stay overnight. For each sample, 300 ml of the filtrate was measured into Pyrex glassware and set on electric hot plate in a fume camber with steady temperature below boiling point 60^0 - 70^0 for three hours to allow gradual evaporation and to avoid excessive loss of the residue until a volume of 20-30 ml was obtained. The remaining filtrate was transferred into 47mm stainless-steal planchet at 10^0C – 20^0 C. This process of heating continues until when the volume of the ground water samples were evaporated to dryness and placed in desiccator to prevent them from absorbing moisture and allow them cool down to room temperature before counting. This process is known as surface drying. Sample residues were dried to constant weight, reweighed to investigate the residue weight using a weighing balance. Having taken the initial weight (of the empty dish), the weight of the residue together with petri-dish will be measured using digital analytical weighing balance. The weight of the total residue obtained from the total volume evaporated will be calculated by using the relation:

$$W_r = W_{(d+s)} - W_d \qquad (1)$$

Where: $W_{(d+s)}$ is the weight of the dish with sample's residue,

W_d is the weight of empty dish

W_r is the weight of the total residue.

0.0770 g of the residue will be transferred to the sterilized planchet and the exact volume that produced this required weight (0.0770 g) will be calculated by the use of the expression:

$$0.0770\ g \times V_{tr} = W_{tr} \times V. \qquad (2)$$

Where: V_{tr} is the volume that generated total residue,

W_{tr} is the weight of the total residue obtained

V is the volume that yielded the required residue

For samples with residue obtained greater than or equal to 0.0770g, the sample efficiency is said to be 100 %. But for the samples with residue less than 0.0770 g, its sample efficiency can be obtained using the expression below;

Sample efficiency = $\frac{\text{weight of residue}}{0.0770\text{g}}$ X 100%. (3.3)

(Semkow, 2001 and WHO, 2014) …... (3)

Instrumentation/Calibration of the Alpha/Beta Counter system

The Alpha/Beta activity concentration measurement was done using low background automatic gross alpha/beta count system (Canberra IMaticTM, USA). Americanium-241 and Strontium-90 standard sources were used to calibrate the system; it was counted 10 minutes later to investigate the efficiency of alpha and beta. The counting efficiency of beta and alpha were 31.01 % ± 2.18% and 69.01% ± 4.39%, respectively. Americanium-241 has higher alpha particle energy (5.49MeV) than those emitted by naturally occurring uranium. It is therefore the prescribed radionuclide for gross alpha calibration. Strontium-90 in equilibrium with daughter Yttrium-90 is the correct radionuclide for gross beta calibration. Calibration was used to count the background radioactivity of the environment. The gross alpha and beta radioactivity counting modes applicable to the counter, with respective voltages of 1,600 and 1,700 volts are employed to count the prepared beer and water samples collected. The counting system will be used to count clear empty planchet in all the counting modes to obtain the background radioactivity of the environment which is needed to be used in the subsequent measurements.

Gross alpha and gross beta activity concentration counting

I. Gross Alpha Counting

For gross alpha counting, the high voltage was set at 1600 V and samples was counted for 3 cycles of 2700 s (45mins) per cycle. The results were displayed as raw counts and count rate (count/min). The data was acquired for alpha mode and the specific activity for alpha in the samples was also calculated using the formula below.

Activity (α) (Bq/L) =

$$\frac{\text{Net count (CPM) }(\alpha)}{\text{DE x 60 x Sample Size (Volume) X Sample Efficiency}} \quad (4)$$

Where D.E is the detector's efficiency and net counts is given by:

Net counts = Raw counts (CPM) – Background (CPM). …… (5).

ii. Gross Beta Counting

The high voltage for gross beta counting was set at 1700 V and samples was counted for 3 cycles over a preset period of 2700 s in beta mode. The specific activities was calculated using the formula below.

Activity (β) (Bq/L) =

$$\frac{\text{Net count (CPM) }(\beta)}{\text{DE x 60 x Sample Size (Volume) X Sample Efficiency}} \quad (6)$$

The parameters remain the same as for equation 5

Alpha/Beta concentration Measurement

The residue were counted for 200 minutes with regards to the procedure selected during the calibration of the instrument to investigate alpha/beta activity concentration within the permissible limit as recommended by [13]. All the samples were counted twice to ensure accuracy and validity and the results were recorded.

Method of Data Analysis

Data obtained from Radiation Protection Institute (RPI), Ghana Atomic Energy Commission (GAEC), Kwabenya Accra, Ghana were saved on a computer Microsoft excel spread sheet and categorized into name of sample and brewery locations of sample collection. The brewery locations and ground water samples were categorized into regions in Nigeria such as East, West, North and South. They were analyzed using descriptive statistics (range, mean standard deviation, frequency, percentage, and tables). Data processing and analysis were carried out using Statistical Package for Social Sciences (SPSS) version 20.0 (SPSS, Inc, Chicago, IL, USA).

Results

Gross alpha and beta activity in water samples across the various site by site breweries in Nigeria.

Result showed that the gross alpha radionuclide activity concentration in water samples from majority of the brewery sites were not safe for brewing or consumption with AW-W_1 site recording the highest activity concentration (0.9330 Bq/L). P-W_1 site recorded the least and safest activity concentration (0.0014 Bq/L) in water. The beta radionuclide activity concentration in brewery water samples from all the brewery sites were apparently safe with ON-W_1 site having the highest concentration (0.694 Bq/L) while P-W_1 recorded the least activity concentration (0.0064 Bq/L).

Geographical area distribution of gross alpha and gross beta activity concentrations in water samples from different breweries in Nigeria.
The gross alpha activity concentration was found to be higher in ground water from the northern part of Nigeria (0.467±0.29 Bq/L), closely followed by that of the south-west (0.462±0.38 Bq/L) but least concentrated in the south-east (0.320±0.43 Bq/L) and then south-south region of Nigeria (0.219±0.26 Bq/L) as seen in (Table 2). The gross beta activity concentration was found to be more in ground water from the northern part of Nigeria (0.4940±0.10 Bq/L) but least activity concentrated in the south-west (0.0280±0.0 Bq/L) with the south and south-east in between (0.2270±0.33 Bq/L and 0.2230±0.31 Bq/L) respectively (Table 3).

Discussions.
Ground water samples from most brewery sites in Nigeria recorded significantly high differential value of gross alpha activity concentration that were above the WHO safe recommended level for drinking water[13]. Also, [14] in Poland recorded high radionuclide activity concentrations in drinking water samples obtained from breweries. These findings may be as a result of the geological formation of the various locations where the ground water samples were collected across different brewery site in the country [9, 15]. In most ground water samples, the gross beta activity concentration was however within the WHO recommended value. Similar findings were also reported in Poland by [14].
Most brewery site in Nigeria recorded high annual effective dose from gross alpha activity concentration in ground water samples. This could be as a result of variation in concentration of radionuclides in our different geological compositions such as in soil, rocks and water which primarily varies from one place to another [2] with the geochemistry and geophysics of such environments also playing a role in radionuclides migration from the rock and soil to water [3]. This shows that consumption or brewing with ground water from the sampled areas poses radiological hazard to the consuming populace since their activity concentration were above the recommended safe limit.

Brewery sites in the northern Nigeria recorded higher estimated annual effective dose due to intake of ground water contaminated with gross alpha and beta emitting radionuclides than samples from south-south breweries. These variations in the radionuclides concentration across the various geographical regions could be attributed to geological characteristics of water, rocks and mineral components as well as the geographical formation of these regions. It could also be as a result of variation in granitic nature of soil, altitude and geomorphic characteristics of different locations [16, 17] which is more in northern Nigeria.
Results show that ground water samples from all the different breweries in Nigeria were not safe for consumption and brewing of beers. This consequently can pose health hazards to the consuming populace with higher preponderance in the northern region since they are above the recommended safe limit.

Conclusion:
The gross beta radionuclide activity concentrations in ground water samples were generally safe in all the sampled breweries. Conversely, the gross alpha activity concentration in most ground water samples were not safe for consumption. The annual effective doses due to gross alpha and gross beta radionuclide activity concentration were relatively not safe for brewing and consumption.

Recommendation:
Following the no threshold model, ground water samples from all the breweries need to be treated to reduce the radionuclide impurities by subjecting ground water through the process of ion exchange technology or reverse osmosis technology before consuming it or using it for brewing of beer to reduce radionuclides concentration and associated hazards on consumers [18].

Conflict of interest: None

Table 1: Gross alpha and beta activity in water samples across the various brewery sites in Nigeria.

Water samples from brewery sites	Region of the Country	Alpha concentration in water (Bq/L) Mean	Inference	Beta concentration in water (Bq/L) Mean	Inference
OG_2-W_1	South-West	0.5220	Not Safe*	0.0083	Safe
IB-W_1	South-West	0.5600	Not Safe*	0.0103	Safe
OG_N-W1	South-West	1.0000	Not Safe*	0.0604	Safe
LG-W_1	South-West	0.0030	Safe	0.0092	Safe
LN-W_1	South-West	0.2230	Not Safe*	0.0500	Safe
U-W_1	South-West	0.5010	Not Safe*	0.0164	Safe
K_1-W_1	North-West	0.2580	Not Safe*	0.5670	Safe
K_2-W_2	North-West	0.6750	Not Safe*	0.4200	Safe
B-W_1	South-South	0.1540	Not Safe*	0.6125	Safe
P-W_1	South-South	0.0014	Safe	0.0064	Safe
EN-W_1	South-East	0.2045	Not Safe*	0.0535	Safe
ON-W_1	South-East	0.0404	Safe	0.6945	Safe
AW-W_1	South-East	0.9530	Not Safe*	0.0629	Safe
AB-W_1	South-East	0.0831	Safe	0.0916	Safe

*The recommended safe reference level activity concentration for water is 0.1 Bq/L for gross alpha activity (WHO, 2004).

Table 2. Gross alpha activity concentrations in water samples across different regional areas in Nigeria

Geopolitical areas	**No. of water samples (n)**	**Range** (Bq/L)	**Mean±SD**	(Bq/L) Inference
North-west	2	0.258-0.675	0.467±0.29	Not safe*
South-south	3	0.001-0.501	0.219±0.26	Not safe*
South-west	5	0.003-1.000	0.462±0.38	Not safe*
South-east	4	0.040-0.953	0.320±0.43	Not safe*

*The recommended safe reference level activity concentration for water is 0.1 Bq/L for gross alpha activity (WHO, 2004).

Table 3. Gross beta activity concentrations in water samples across different regional areas in Nigeria

Geopolitical areas	**No. of water samples (n)**	**Range**(Bq/L)	**Mean±SD** (Bq/L)	Inference
North	2	0.420-0.567	0.494±0.10	Safe
South	3	0.006-0.613	0.227±0.33	Safe
South West	5	0.083-0.604	0.280±0.03	Safe
South East	4	0.054-0.695	0.223±0.31	Safe

*The recommended guideline activity concentration is 1.0 Bq/L for gross beta activity (WHO, 2004).

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